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# OAK

## . . an American wood

Oaks form the most important and abundant group of hardwood trees in North America and probably in the Northern Hemisphere. Collectively, the red and white oaks comprise about one-third of the total hardwood volume in the United States. There are some 80 species and numerous hybrids, most of them east of the Great Plains. They are important producers of hardwood timber and veneers of excellent quality as well as outstanding beauty of grain and figure. Oak wood is strong, hard, and tough; has good working characteristics; and is used extensively for furniture, flooring, paneling, ties, and cooperage.

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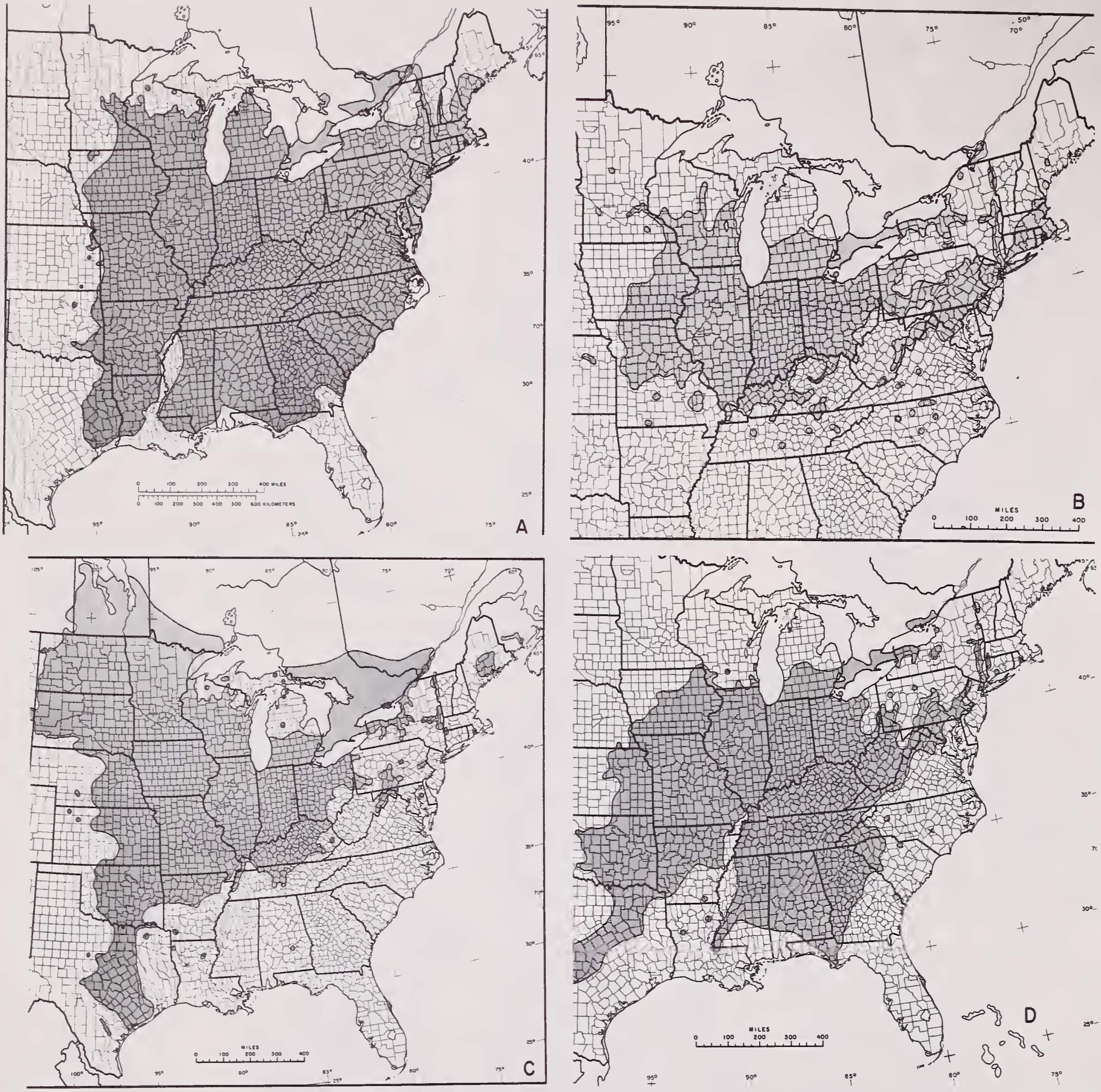

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Figure 1.—Natural range of white oak (A), swamp white oak (B), bur oak (C), chinkapin oak (D).

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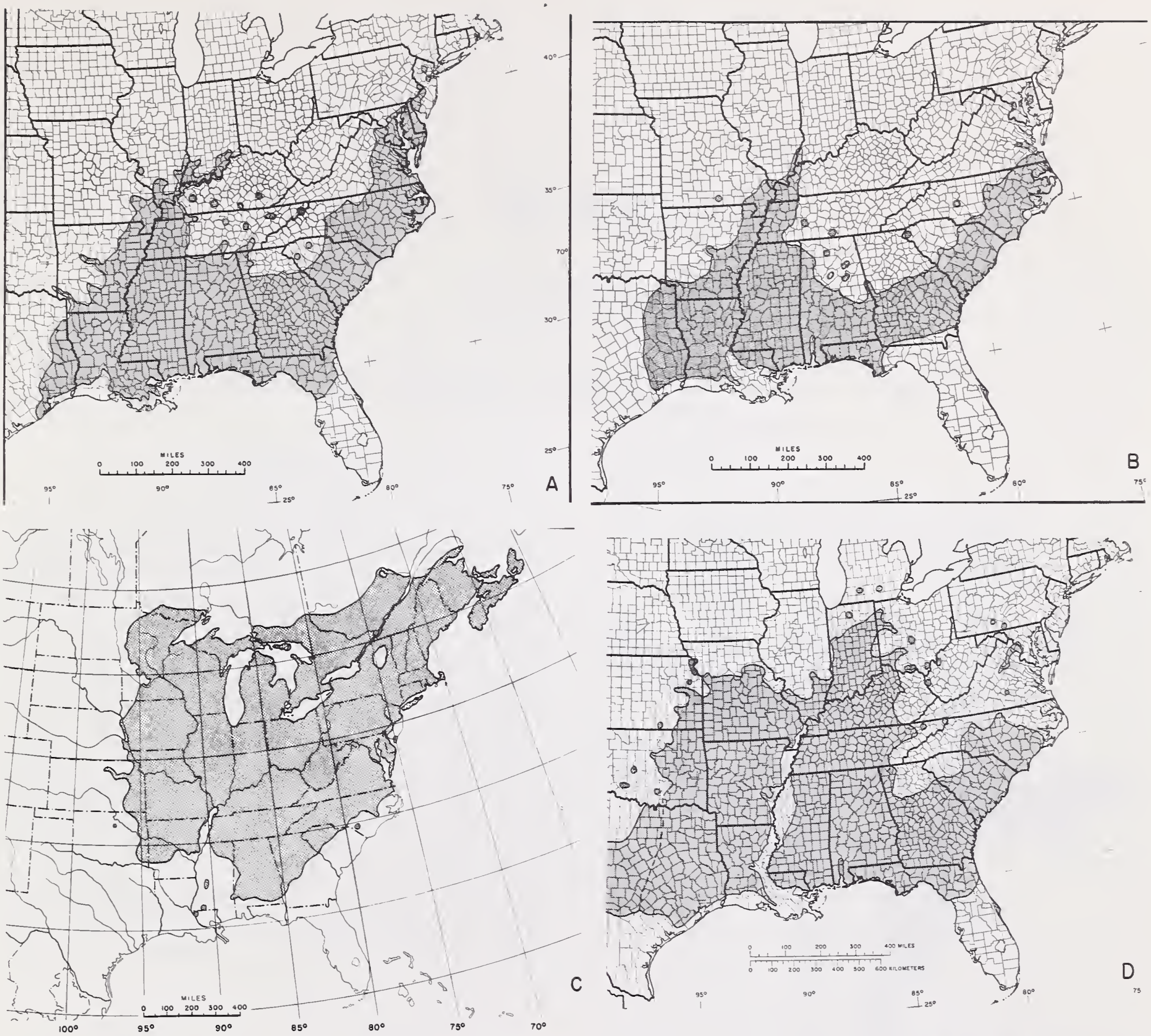

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**Figure 2.—Natural range of swamp chestnut oak (A), cherrybark oak (B), northern red oak (C), Shumard oak (D).**

# OAK

## . . . *an American wood*

Glenn A. Cooper and Richard F. Watt[1]

### DISTRIBUTION

The 20 species of oaks (*Quercus* spp.) of importance as a source of wood and fiber in the Eastern United States are listed in table 1 (p. 5), the white oak group, and in table 2 (p. 6) the red oak group. Scientific and common names, growth characteristics, and leaf and acorn descriptions are summarized. Eight of the species — white, swamp white, bur, chinkapin, swamp chestnut, cherrybark, northern red, and Shumard oaks — have been designated as "select" species because of the volume of the wood produced and the quality of the product. Their ranges are shown in figures 1 and 2.

Commercially important stands of oaks are found in all of the States east of the Great Plains. Many of the important species, such as bur, northern red, black, and white oak are present and are cut in significant quantity in all the Eastern States.

### DESCRIPTION AND GROWTH

Botanically, native species can be divided into two main groups or subgenera, the white oaks, *Leucobalanus*, and the red oaks, *Erythrobalanus*. The white oak leaves lack bristles or spines at the end of the lobes or teeth (fig. 3); the acorns are generally sweet, mature in one growing season, and germinate in the fall when they drop to the ground. The bark is usually light gray and scaly (fig. 4). In contrast, leaves of the red oaks have a bristle at the end of the lobes or teeth (fig. 5); the bitter acorns mature at the end of the second season and the shell inner surface is densely covered with hairs. The acorns do not germinate until the spring. Those red oaks with entire leaf margins have a bristle tip at the leaf apex or bristles along the margin. Red oak bark is dark, furrowed, and often blocky (fig. 6).

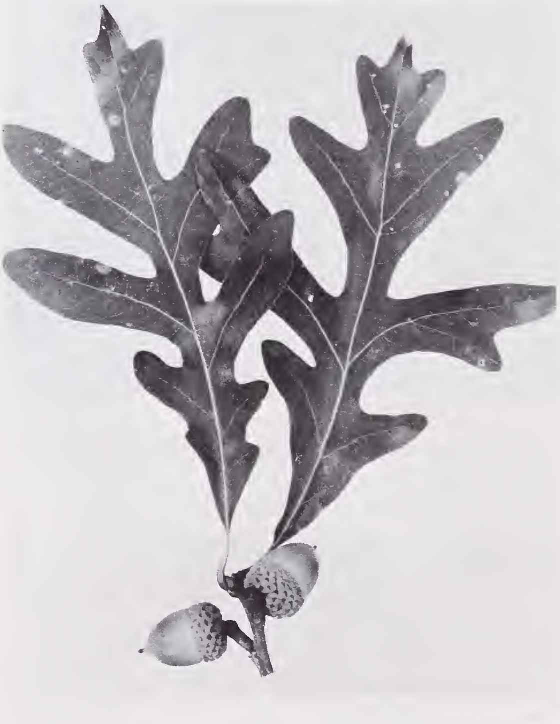
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**Figure 3.—White oak leaves, twig, and acorns.**

The inconspicuous flowers of the oaks appear in early spring at the time of leaf flushing. Male flowers

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NOTE: This publication supersedes unnumbered publication *Oak*, issued 1959.

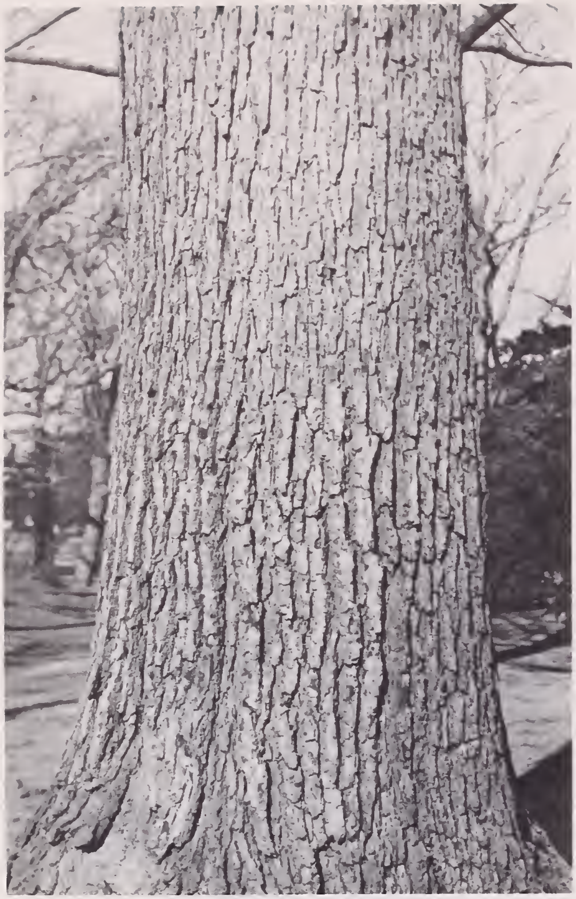

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Figure 4.—White oak bark.

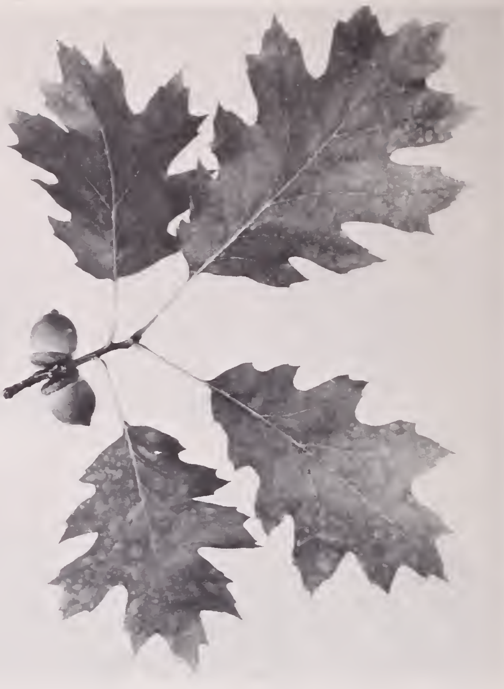

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Figure 5.—Red oak leaves, twig, and acorns.

are borne in clustered, yellowish-green catkins about 3 inches long. Tiny female flowers are borne in the axils of the new leaves and are found only upon close examination. Oaks are monoecious, that is, male and female flowers are borne upon the same tree. The flowers are wind-pollinated and the ground under a dense stand of oak may be tinted yellow with the copious pollen.

These 20 oaks are found growing on a wide range of sites, from the wettest to the driest, from sea level to 5,000 feet and more in the Appalachian Mountains. They are associated with most of the recognized forest types of the East.

Live oak is a typical tree of the southern Atlantic and gulf coast plain, surviving salt spray and inundation by high tides. Important associates are southern magnolia, sweetbay, American holly, flowering dogwood, hawthorn, and pignut hickory. With its shiny evergreen leaves and widespreading branches, live oak is a favorite landscaping tree, and is often picturesquely draped with Spanish moss.

A number of oaks are found in moist bottoms and swamps, often inundated by high water. Pin, willow, water, swamp white, and overcup oaks fall in this group. Trees associated with them are red and silver maples, American and cedar elm, sweetgum, sugarberry, water locust, pecan and hickory, Nutall oak, green and black ash, basswood, sycamore, and willows. The pin oak, another favorite for landscaping, transplants readily; grows rapidly; and has a straight central stem, a compact crown, and brilliant fall coloration. The willow oak, a widely planted street tree in Southern States, grows rapidly and, because of its small leaves, produces a delicate-appearing, lacy crown.

Other oaks are found on moist but well-drained sites along stream bottoms, in coves, and on northern and eastern slopes. Cherrybark, laurel, northern red, Shumard, white, and swamp chestnut oaks typically grow on these sites. Northern red and white oaks may become massive, widespreading, and long-lived trees that are ideal for landscaping large areas around homes. Forest associates found in various combinations with these oaks are shagbark, shellbark, mockernut, and bitternut hickories; yellow-poplar; basswood; white ash;

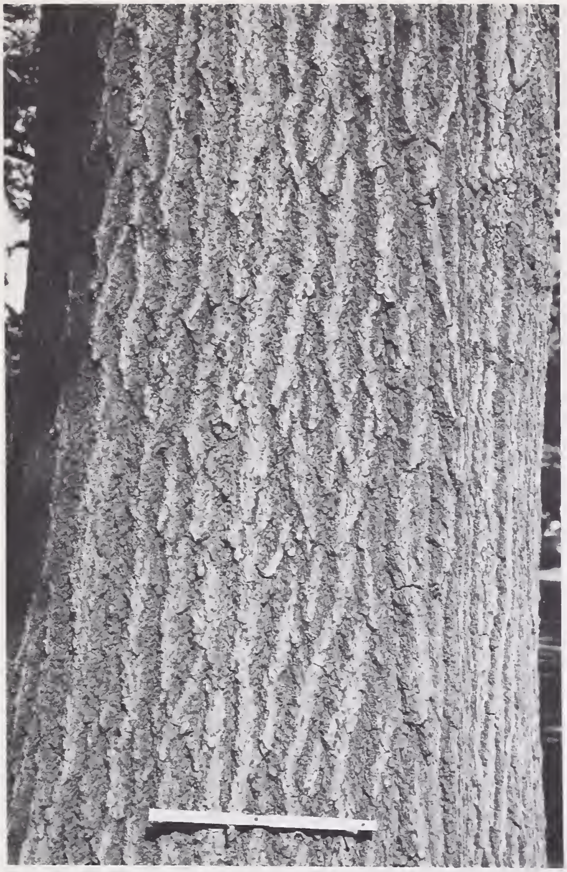

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Figure 6.—Red oak bark.

southern red oak; eastern white and shortleaf pine; blackgum, sweetgum; sassafras; southern magnolia; boxelder; cottonwood; honey and black locust; walnut and butternut; sugar and red maples; and American and cedar elms.

Those oaks found on poor, dry upland and ridge sites are chinkapin, chestnut, post, scarlet, southern red, blackjack, and black oaks. However, these oaks will generally do well on better sites when they can establish themselves. Some trees commonly growing with them are hickories; sweet and black gum; red and sugar maple; northern pin oak; Virginia, white, and loblolly pines; black cherry; and black locust.

Bur oak grows in conditions ranging from the relatively moist bottoms in its southern extent to the dry prairie fringes at its northwestern limits. Consequently, it can be found associated with nearly all of the trees mentioned above.

Oak growth rates depend upon the site and species of tree. The fastest growth rates are associated with fertile sites well supplied with moisture in a climate where there is a long growing season. Cherrybark, pin, scarlet, northern red, water, and Shumard oaks are considered rapid-growing species. Post, blackjack, chestnut, black, and chinkapin oaks are slow-growing species.

Root systems will naturally vary with the condition under which the species are growing. Generally, those species growing on wet soils will have a shallow root system, whereas those on drier and deeper soils will develop deep taproots augmented by a widespreading array of surface roots.

All oaks sprout readily after killing of the stem, although sprouting ability decreases with age of the stump. Thus, they are well able to survive fire, cutting, and other forces which kill the aboveground portion of the plant.

As a group, oaks produce infrequent and irregular seed crops. Good crops come at 4- to 7-year intervals. A large proportion of the acorns are insect-infected. Many mammals and birds seek them. Thus, abundant seedling reproduction is unlikely except during a year of bumper crop. Acorns and fleshy taproots of young seedlings are avidly sought by range hogs; closing of the range in most States has removed this deterrent to successful reproduction. Early seedling growth is typically slow, in the range of 6 inches a year for the early years. In contrast, sprouts will often grow 6 feet a year for the first 2 or 3 years.

Although their strong sprouting habit permits them to persist under repeated burning, fires are a serious cause of damage and death to oaks. The thin bark of young stems makes them particularly susceptible to injury, but intense fires will injure the bark even on old trees and permit entrance of decay organisms and insects. The thin bark of laurel and live oak makes fire particularly damaging, even to large trees of these species. Wounds from large broken limbs and fire provided entrance courts for most of the heart rot in present merchantable stands.

A number of fungi attack the foliage of oaks, but the most serious disease is the oak wilt, *Ceratocystis fagacearum*, which is widespread in the Central States and in some of the Eastern ones. Trees of the red oak group are highly susceptible and are killed during the year of infection. No control is practical, but fortunately the disease kills only scattered individuals or small groups of trees in a stand. It has not affected timber supply or lumber production.

A number of trunk-boring insects of the genera *Goes*, *Prionoxystus*, and *Romaleum* cause heavy losses by their larval tunnels in the trunk. Oaks are a favored host of the gypsy moth, *Porthetria dispar*, a serious defoliator in the Northeastern States. Repeated defoliation may kill trees, but most attacks are not this intense and long lasting.

## COMMON NAMES

Common names of all the commercial red and white oaks are given in tables 1 and 2. Local usage of common names may vary somewhat from that given in the tables.

## RELATED COMMERCIAL SPECIES

Red oak and white oak are the common names applied to all the related species in each group of woods. In commerce the woods are all sold under these two names.

## SUPPLY

Oaks, the principal hardwoods in the commercial forest land in the United States, constitute 7 percent of the total U.S. sawtimber volume and about 34 percent of the hardwood sawtimber volume. In 1963 the total stand of oak sawtimber in the Eastern United States was estimated at over 72 billion board feet of white oak and almost 90 billion board feet of red oak. About 89 percent of the Eastern hardwood stand is privately owned. Both red and white oak sawtimber stands exist in every Eastern State; but in 1963 the Central region of Illinois, Iowa, Missouri, Indiana, Kentucky, Tennessee, Kansas, Nebraska, and Ohio contained about 25 percent of the entire resource. Kentucky led the other states in 1963 with about 8.4 percent of the oak sawtimber volume.

Presently, oak growth is exceeding the cut; but the growth is in small trees. In 1962 the growth of all oak 5 inches and over was double the cut; the growth of oak sawtimber (trees 11 inches and larger) was 40 percent over the cut, but 53 percent of it was in undesirable species; and the bigger trees, which are the backbone of the hardwood industry, had declined. Thus, there is overcutting of the trees larger than 15 inches, and a surplus of the smaller diameter trees. Furthermore, the smaller trees could be harvested in intermediate cuttings and benefit the remaining stand.

Sawtimber size and the grades of the lumber yielded are directly related. Thus, a general decline in the supply of oak sawtimber 15 inches and over has led to a decline in the availability of high-grade lumber that will yield large, defect-free parts. In 1963 the Eastern hardwood sawtimber, of which one-third is oak, was only about 11 percent No. 1 factory lumber logs. About 18 percent was judged No. 2 lumber logs; 48 percent, No. 3 lumber logs; and 23 percent, grade 4 logs used for ties.

## PRODUCTION

The production of oak lumber has changed considerably over the years with changing technology and need. Lumber production increased from 1869 to its peak of 4.5 billion board feet in 1899 (fig. 7). With the decreased availability of Eastern oaks and the increased availability of west coast softwoods, the use of oak gradually declined to 0.6 billion board feet in 1933. Since then, more consumer demand for furniture, flooring, and other products made from oak lumber has caused a gradual production rise. In 1955 oak lumber production in the Eastern United States was up to an estimated 3.7 billion feet, and in 1969 the projected production was 3.4 billion feet.

The production of oak in forms other than lumber is also increasing. In 1965 oak was used for 47 percent of all the treated crossties in the United States—over 9 million ties. Tie production bottomed out in the early 1960's with the decline of railway mileage, increased tie life, and deferred maintenance. However, tie production is expected to increase and level off in the 1970's.

The production of oak bolts used for hardwood dimension and cooperage, and the peeling of oak veneer logs for furniture, containers, and plywood increased from 1940 to 1965. With the development of improved pulping methods, oak manufacturing residues and low-grade stems not suitable for lumber have been increasingly used for pulp production. More complete utilization of all wood, especially manufacturing residues, is one of the goals of the hardwood industry.

Oak wilt losses have had no significant effect on either the supply of oak timber or the production of oak lumber and other products.

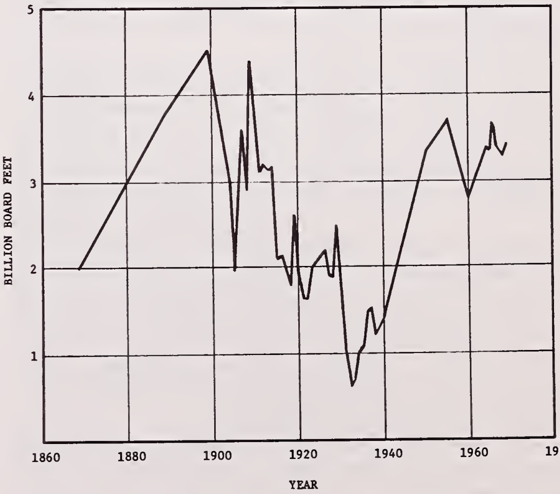

**Figure 7.—Production of oak lumber.**

Table 1. Characteristics of important white oak species (Leucobalanus - white oak subgenus)

| Scientific Name | Common Names** | Growth Characteristics | Leaf Description | Acorn |
|---|---|---|---|---|
| *Q. alba L. | White oak, fork leaf white oak, stave oak. | Large tree commonly 100 feet tall, straight boled; found on variety of soils and sites. | Deciduous; oblong-obovate, 5-9 inches long, 2-4 inches wide, 7-9 deep or shallow sinuses; bright green above, paler below. | 3/4" long; ovoid-oblong, bowl-like cup with warty scales. |
| *Q. bicolor Willd. | Swamp white oak, white oak. | Medium-sized tree, 70-80 feet tall; typical of lowlands, swamp edges, and wet flats. | Deciduous; obovate, 5-6 inches long, 2-4 inches wide, coarsely dentate or irregularly shallow lobed; lustrous dark green above, paler and tomentose below. | 1" long ovoid nut borne on long stalk; enclosed one-third in slightly fringed cup. |
| Q. lyrata Walt. | Overcup oak, swamp post oak, swamp white oak, water white oak. | Medium-sized tree, typically 80 feet tall; growing on lower poorly-drained first bottoms and terraces. | Deciduous; oblong-obovate with 5-9 irregular lobes; green and glabrous above and below or silvery white and downy below. | Subglobose 3/4" acorn; nearly enclosed by deep, unfringed cup. |
| *Q. macrocarpa Michx. | Bur oak, blue oak, mossycup oak, scrub oak. | Large tree on better sites, often 100 feet tall; frequently on dry thin soils, intruding into dry prairies but also in moist bottoms of midwest. | Deciduous; 6-12 inches long, 3-6 inches wide, obovate with 5-9 lobes, two deep center sinuses; dark green lustrous above, pale and pubescent below. | Ovoid 1-1/2" nut; half enclosed in deep fringed cup. |
| *Q. michauxii Nutt. | Swamp chestnut oak, basket oak, cow oak. | Medium-sized tree 60-80 feet tall of well-drained terraces and first bottom ridges of large and small streams. | Deciduous; 5-8 inches long, 3-4 1/2 inches wide, broadly obovate, coarsely crenate; dark green and lustrous above, silvery white and pubescent below. | Ovoid 1-1/4" acorn; not more than 1/3 enclosed in thick cup. |
| *Q. muehlenbergii Engelm. | Chinkapin oak, chestnut oak, rock oak, yellow chestnut oak, yellow oak. | Medium-sized tree 60-80 feet tall; associated with well-drained dry sites on limestone formations. | Deciduous; 4-7 inches long, 1-4 inches wide; oblong-lanceolated, coarsely serrate; yellow-green glabrous above, pale and finely pubescent below. | Ovoid 3/4" nut; half enclosed in thin cup, dark brown to nearly black. |
| Q. prinus L. | Chestnut oak, rock chestnut oak, rock oak. | Medium-sized tree 60-70 feet tall; typically of dry sandy or gravelly soils but is found in coves and well-drained bottoms. | Deciduous; 4-8 inches long, 1 1/2-3 inches wide; elliptical, coarsely crenate; yellowish-green and lustrous above, paler and often finely pubescent below. | Ovoid 1" nut, very lustrous; 1/3 to 1/2 enclosed in thin cup. |
| Q. stellata Wangenh. | Post oak, iron oak. | Small to medium-sized tree, 30-60 feet tall, depending on site. Typical of dry rocky ridges, gravels, and sands, also of heavy soils, that are alternately waterlogged and hard and dry. | Deciduous and leathery, 4-6 inches long, 3-4 inches wide oblong-obovate, 5 lobes with cruciform appearance, surfaces dark green with stellate pubescence above, tomentose below. | Ovoid-oblong 1/2" nut, sometimes striped; enclosed 1/3 of length in cup with thin scales. |
| Q. virginiana Mill. | Live oak, Virginia live oak. | Medium-sized tree from 40-60 feet tall; nearly always on deep sandy soils. Highly resistant to salt spray. | Persistent until following spring; 3-5 inches long, 1/2-2 1/2 inches wide, elliptical; margin entire and revolute, dark glossy green above, paler and pubescent below. | Ellipsoidal 3/4" acorn borne on stalk in clusters of 3-5; 1/3 enclosed in turbinate cup; dark brown to nearly black. |

* Indicates "select" oak species.
** First listed name is the preferred common name.

**Table 1.**

## CHARACTERISTICS AND PROPERTIES

Within each oak group the various woods cannot be positively identified, but usually an oak can be discerned as red or white by the heartwood color and the presence or absence of plugged pores. White oak probably got its name from its light-gray bark, not from the color of the heartwood, which varies from a rich, light or grayish brown, to dark brown. The red tinge characteristic of red oak heartwood is usually absent in the white oaks. The sapwood of both groups of woods is almost white to very light brown and its thickness varies from 1 to 2 inches or more.

Oak growth rings are very distinct (figs. 8, 9). The clearly visible tubelike pores formed at the beginning of a growing season are much larger than those farther out in the same ring. In the white oaks, except in the outer sapwood, these pores are usually plugged by frothy-appearing growths called tyloses (fig. 8). These pore plugs make white oaks impermeable. Red oaks usually lack tyloses (fig. 9). Large pores also give the oaks their coarse texture. Broad medulary rays show as light-colored radial lines on the end grain and as dark-colored distinct

Table 2. Characteristics of important red oak species (Erythrobalanus - red oak subgenus)

| Scientific Name | Common Names** | Growth Characteristics | Leaf Descriptions | Acorn |
|---|---|---|---|---|
| Q. coccinea Muenchh. | Scarlet oak, black oak, red oak, Spanish oak. | Medium to large tree, occasionally 100 feet tall, short-boled; characteristic of dry sandy soils. | Deciduous; 4-7 inches long, 3-5 inches wide; obovate, deeply 7-9 lobed with wide sinuses; lustrous green above, paler and glabrous below except for axillary tufts. | 1/2-1" long; 1/3 to 1/2 enclosed in bowl-like cup. |
| Q. falcata Michx. var. falcata | Southern red oak, red oak, Spanish oak, water oak. | Medium-sized tree, 70-80 feet tall, with short trunk and extensive rounded crown; typically found on dry poorer soils of uplands and ridges. | Deciduous; obovate, 5-9 inches long, 4-5 inches wide; 5-7 lobes, often falcate, terminal lobe often very long; dark lustrous green above, grayish green tomentose below. | 1/2" long; subglobose, sometimes striate and with stellate pubescence; enclosed 1/3 or less in shallow cup. |
| *Q. falcata Michx. var. pagodaefolia Ell. | Cherrybark oak, bottomland red oak, Elliott oak, swamp red oak, swamp Spanish oak. | Large tree, 80-120 feet tall with long massive trunk; found on rich bottomlands and old fields. | Deciduous; obovate to oval; 5-9 inches long, 4-5 inches wide, 5-11 narrow uniform lobes; dark green and lustrous above, paler and tomentose below. | 1/2" long, subglobose, cup enclosing about half of nut. |
| Q. laurifolia Michx. | Laurel oak, Darlington oak, obtusa oak, diamond leaf oak. | Medium-sized tree, 50-60 feet tall; growing in moist but well-drained sandy soil adjacent to streams and swamps. | Semi-evergreen, falling shortly before new leaves appear in spring; elliptical; 2 1/2-4 inches long, 1/2-1 inch wide, margin entire; lustrous green above, paler below with yellow midrib. | 1/2" long; ovoid to hemispherical; dark brown to nearly black; 1/4 or less enclosed in thin saucer-like cup. |
| Q. marilandica Muenchh. | Blackjack oak, barren oak, black oak, jack oak. | Small tree, 20-30 feet tall with short trunk and numerous branches; characteristic of dry, sandy, sterile soils. | Deciduous; obovate or triangular; 6-7 inches long, 2-3 inches broad, shallowly 3-lobed at apex; lustrous dark yellow-green above, orange-pubescent below. | 3/4" long; oblong to ovoid; striate, 1/2 enclosed in thick bowl-shaped cup. |
| Q. nigra L. | Water oak, possum oak, spotted oak. | Medium-sized tree, but will frequently reach 100 feet; straight slender trunk; grows best in moist alluvial bottomland soils but seldom in permanent swamps. | Deciduous, although some leaves persist until late winter; spatulate, oblong-lanceolate 2-4 inches long, 1-2 inches wide; entire, 3-lobed at apex or variously pinnatifid-lobed; glabrous except for occasional axillary tufts below. | 1/2" long; hemispherical, nearly black, often striate; enclosed at base with thin saucer-like cup. |
| Q. palustris Muenchh. | Pin oak, Spanish oak, swamp oak, swamp Spanish oak. | Large tree, 70-90 feet tall but up to 120 on best sites; found on wet sites of stream bottoms, often on heavy poorly drained soils. | Deciduous; obovate to oval; 3-5 inches long, 2-5 inches wide; 5-7 lobed with deep irregular sinuses; dark lustrous green above, paler below with axillary tufts. | 1/2" long; hemispherical often striated with darker lines; enclosed only at base in thin shallow cup. |
| Q. phellos L. | Willow oak, peach oak, pin oak, swamp willow oak. | Medium to large tree up to 120 feet tall, with straight tall trunk; characteristic of wet stream bottoms and swamps. | Deciduous; linear-lanceolate, 2-5 inches long, 1/3-1 inch wide; margin entire; light green and glabrous above, paler below and rarely tomentose. | 1/2" long or less; hemispherical, somewhat pubescent; enclosed at base by thin shallow cup. |
| *Q. rubra L. | Northern red oak, gray oak, common red oak, eastern red oak, mountain red oak. | Medium-sized tree about 70 feet tall, but may obtain heights over 100 feet with a tall columnal bole free of branches; typically found on deep soils on cool slopes and coves. | Deciduous; oblong to obovate; 5-8 inches long, 4-5 inches wide; regularly 7-11 lobed with sinuses extending halfway to midrib; dark green and glabrous above, paler below with occasional axillary tufts. | 1/2" long; ovoid to oblong; pubescent towards apex; cup variable from saucer shaped to deep and enclosing 1/3 of acorn. |
| *Q. shumardii Buckl. | Shumard oak, Schneck oak, southern red oak, spotted oak. | Large tree, 90-125 feet and taller with long clear bole; commonly found on well-drained bluffs and terraces of streams although found on drier sites at western end and northern edge of its range. | Deciduous; 6-8 inches long, 4-5 inches wide; obovate to oval; 7-9 lobes often again divided with many bristle tips; dark green and lustrous above, paler and glabrous below with axillary tufts. | 3/4-1 1/4" long; oblong-ovoid tapering slightly to tip; 1/4 enclosed by thick saucer-shaped cup. |
| Q. velutina Lam. | Black oak, smooth-bark oak, yellow oak, quercitron oak. | Large tree generally not over 80 feet tall but may reach 150 feet; typically growing on dry sandy or rocky ridges or heavy hillside clays. | Deciduous; 5-7 inches long, 3-5 inches wide; ovate, 5-7 often toothed lobes; dark lustrous green above, yellow-green to coppery below, more or less scurfy pubescence and conspicuous axillary tufts below. | 1/2-3/4" long; ovoid to hemispherical, often striate; 1/4 to 1/3 enclosed in a deep bowl-like cup. |

* Indicates "select" oak species.
** First listed name is the preferred common name.

**Table 2.**

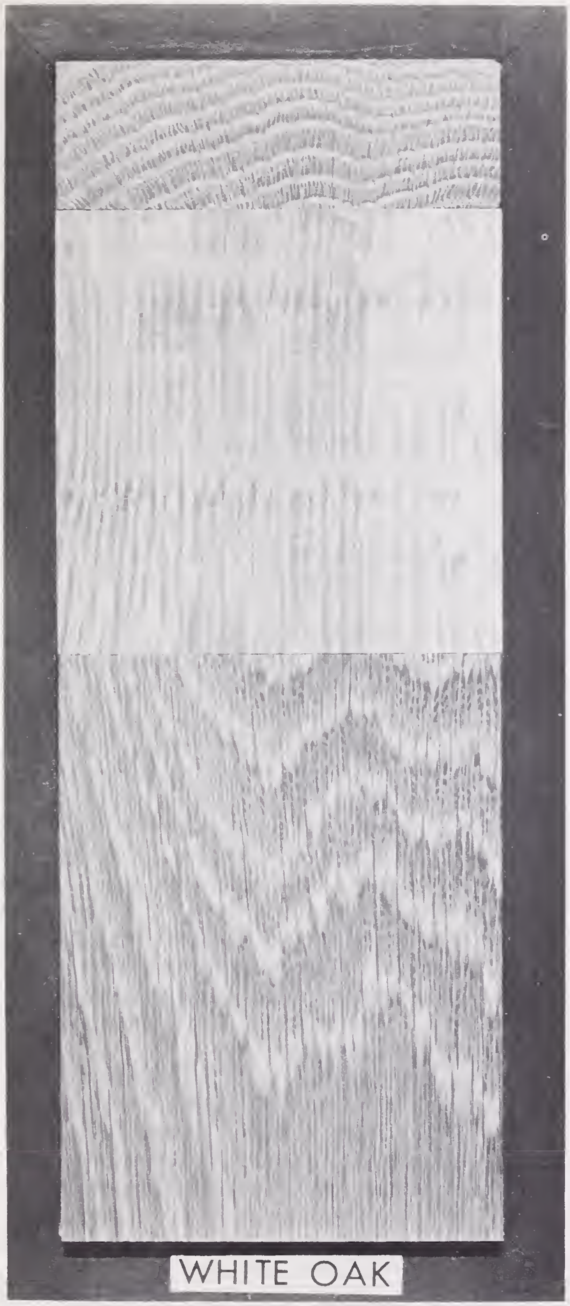

Figure 8.—White oak. In the transverse view (top) the rays are straight lines resembling radii and the light wavy bands are the springwood pores at the beginning of each annual ring. The pores are mostly plugged with tyloses. On the right edge of the radial section (center) the ray flecks are visible as crescents and ribbons. The tangential view (bottom) shows the wavy pattern of the annual rings.

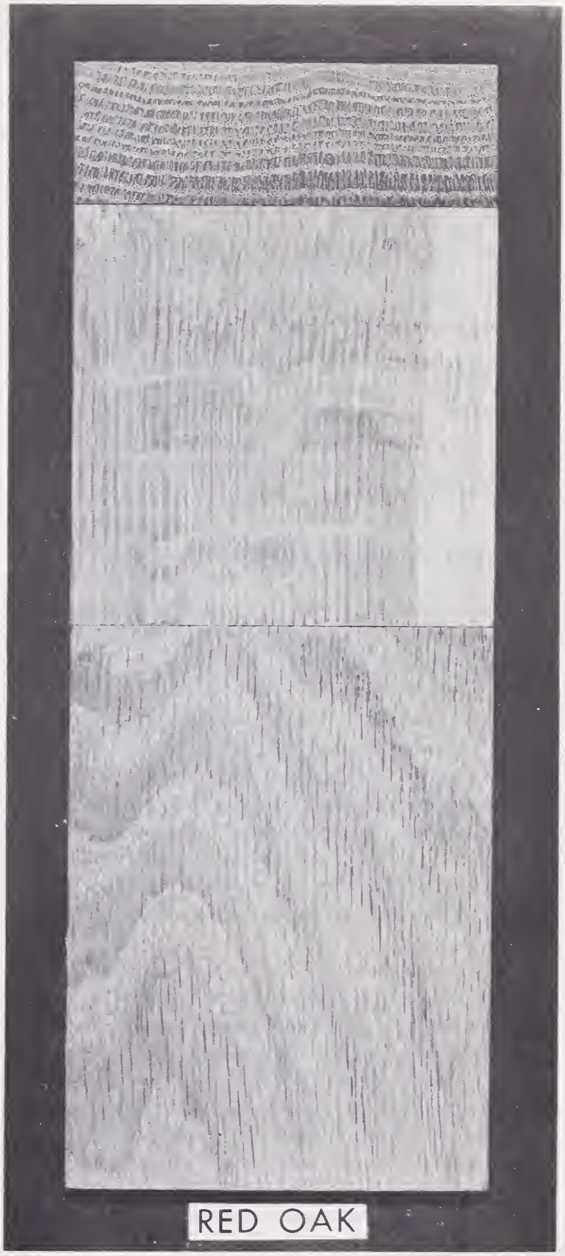

Figure 9.—Red oak. The transverse section (top) clearly shows the open pores without tyloses (compare this to fig. 8). The radial face (center) shows bands of ray cells which are usually narrower than in white oak. At the bottom is the tangential section.

flakes or ribbons on the quartersawn faces. These often give the wood a striking figure. In white oak the rays are generally larger than in red oak, the larger ones up to 5 inches in height along the grain. Red oak rays are usually less than 1 inch high along the grain.

The oaks are relatively heavy woods. White oaks average about 47 pounds per cubic foot except for live oak, which weighs about 62 pounds per cubic foot. Specific gravity of the white oaks varies from 0.57 in chestnut oak to 0.81 in live oak.[2] The red oaks as a group average about 44 pounds per cubic foot, and specific gravity ranges from 0.52 to 0.60. Oak is usually straight-grained, hard, quite strong, very stiff, and tough. The swamp chestnut oak and overcup oak are not as strong as the other white oaks, but as a group the white oaks and red oaks have about equal strength properties. Fast-grown oak with wide growth rings has better strength properties and is heavier than slow-grown oak.

Oak has long been a favorite wood because of its good working characteristics. It machines and glues well, and holds fasteners exceptionally well. However, it tends to split when nailed, and predrilling pilot nail holes is a common practice to avoid splitting. Oak also finishes well, and because it has coarse grain, a variety of color effects are possible by varying the filler applied to the pores before the lacquer or varnish finish.

Oaks tend to shrink considerably, and they must be dried more slowly than many other hardwoods. Drying too quickly in a kiln can cause end and surface checking, honeycombing, and collapse, particularly in 2-inch and thicker lumber. Properly controlled kiln-drying minimizes drying defects and improves the strength and working properties of oak.

The heartwood of white oak is more decay-resistant than the heartwood of red oak and most other hardwoods, and ranks about equal to southern pine and Douglas-fir. The white oaks cannot be impregnated readily with preservatives because of the tyloses-plugged vessels, but the impermeability of the white oaks makes them highly valued for tight cooperage. Chestnut oak is an exception: It is a white oak, but usually lacks tyloses. The red oaks are low in decay resistance, but lacking tyloses they are easily penetrated and made durable with preservatives. Commercial oak lumber usually contains fewer, but larger, knots than most softwood lumber. Much of the low-quality oak timber not good for lumber is best utilized for paper pulp. Oaks reduce readily to pulp, yielding about 45 percent sulfite or kraft pulp.

## PRINCIPAL USES

The use of oak has been closely tied to American history and changing technology. Because of its outstanding durability and strength characteristics, oak was used extensively for shipbuilding until after the Civil War. In 1828 President John Quincy Adams set aside the Naval Live Oaks Plantation, the first forest land reserved by the U.S. Government, to conserve white and live oak for the large wooden sailing ships of that era. The use of oak for shipbuilding diminished as the Navy shifted to steel; nevertheless, today about 4 million board feet, mostly white oak, is still used annually for shipbuilding and boatbuilding.

As the western United States was opened up by the growing web of railroads, white oak was utilized to meet the demand for strong and durable ties. The less durable red oaks were also utilized, but usually only with preservative treatment. Oak is still the leading wood used in tie production.

As Americans raised their standard of living, their needs for products which utilized the strength, durability, and beauty of oak changed. During the settlement of the Middle Western States, white oak shingles and shakes were important products. Today they are only made by local craftsmen for special purposes. The use of oak for tannin dyes and fuelwood has almost ended. Tubs, railway cars, agricultural implements, nonmotor vehicles, and sporting goods formerly consumed much oak; but substitute products and materials have almost ended these uses. By far the greatest single use of oak today is for hardwood dimension and flooring, and it is growing. Household and public furniture made of oak has always been popular, and in 1965 over 200 million board feet of oak lumber was used in the furniture industry.

Oak is widely used as veneer and plywood in millwork and furniture. In 1928, before the depression of the 1930's, about 7 million square feet of oak veneer and plywood (1-inch basis) were used for millwork and furniture. In 1933 consumption dropped to about 1 million square feet. Since then, use has increased and in 1960 it was over 13 million square feet.

White oak continues to be the outstanding wood for tight barrels, kegs, and casks for the storage and curing of whiskey and wine. The flavor and quality of these beverages is improved by storage in oak barrels. No substitutes have been found which are as fully satisfactory. Oak is used in vehicles for truck and trailer beds because of its toughness and resistance to wear. It is also extensively utilized for mining timbers, containers, pallets, caskets, boxes, paneling, and jigs.

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[2] At 12 percent moisture content.

Thus, in spite of substitutes and changing products, oak has been used in increasing quantities since 1948 to satisfy consumer demands for its beauty, strength, and durability in many ways; and in 1965 about 29 percent of all the native hardwood lumber used in American manufacturing industries was oak.

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